

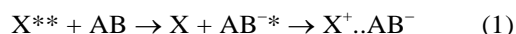
Rydberg atom scattering in K(12p)-CH₃NO₂ collisions: role of transient ion pair formation

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Synopsis Studies of K(12p)-CH₃NO₂ collisions reveal unusually strong Rydberg atom scattering which is attributed to the formation of transient K⁺..CH₃NO₂⁻ ion-pair states.

Collisions between low-*n* Rydberg atoms and attaching targets can lead to formation of weakly-bound ion-pair states through electron transfer reactions of the type



where AB^{-*} is a short-lived excited state populated by initial electron capture, AB⁻ is a long-lived metastable anion formed by intramolecular vibrational relaxation, and X⁺..AB⁻ is an ion-pair state. Ion-pair states represent a novel class of long-range molecules which, as shown by recent measurements, possess unusual physical and chemical properties [1].

Earlier studies of reaction (1) have focused on targets that form valence-bound anions. Low-*n* Rydberg collisions with polar targets can also lead to formation of dipole-bound negative ions. We explore the role of dipole binding in forming ion-pair states using CH₃NO₂ whose dipole moment is sufficient to support a dipole-bound state but that can also form long-lived valence-bound anions. As shown in Fig. 1a, pulses of K(12p) atoms are photo-excited near the center of a gas cell where they interact with the target gas. A fraction of the neutral reaction products exit through a slit and enter an analysis region where they are subject to a transverse, pulsed electric field. The resulting negative particles are detected by a position sensitive detector that records their arrival times and positions. The particles are observed to be electrons produced by field ionization of scattered Rydberg atoms. No long-lived ion-pair states are seen. The electron arrival position distributions point to strong Rydberg atom scattering with a collision cross section comparable to the geometric size of the Rydberg atom itself.

Rydberg scattering is attributed to ion-ion scattering through formation of transient ion-pair states with lifetimes ≥10 ps via transitions between the covalent K(12p)+CH₃NO₂ and ionic K⁺..CH₃NO₂⁻ terms in the quasi-molecule

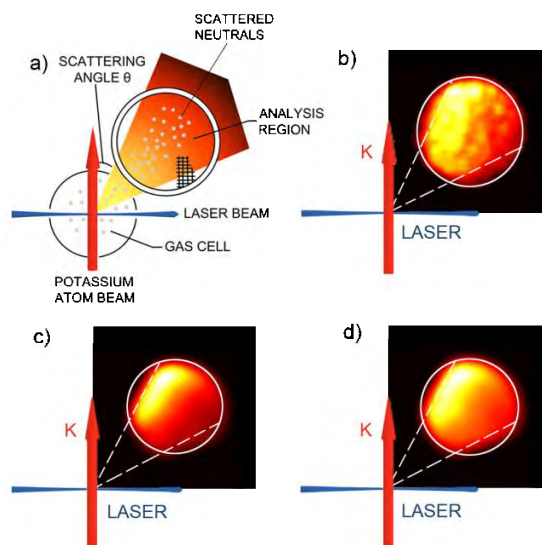


Figure 1. a) Schematic of the experimental approach. b) Measured spatial distribution of scattered Rydberg atoms following a 50 μs flight time. c), d) Results of model calculations that assume ion-pair lifetimes of 10 and 100 ps, respectively.

formed during collision. The CH₃NO₂⁻ lifetime is limited by electron detachment induced by the field of the K⁺ ion, the detached electron remaining bound to the K⁺ ion in a Rydberg state. The large reaction rate observed is consistent with theoretical calculations of resonant quenching, i.e., *n*, *ℓ* changing, in Rydberg collisions with CH₃NO₂. [2]

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References

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- [2] A.A. Narits, E.S. Mironchuk, and V.S. Lebedev 2016 *J. Phys. B: At. Mol. Opt. Phys.* **49** 124001

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